CITY OF WINTERS

STORM DRAINAGE MASTER PLAN

Prepared by:

CH2M Hill

Adopted
May 19, 1992

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Prepared for

CITY OF WINTERS

REGISTERED PROFESSIONAL ENGINEER
DAVID A. PETERSON
No. C 043432
Exp. 6/30/92
CIVIL
STATE OF CALIFORNIA

This document has been prepared under the direction of a Registered Professional Engineer

Prepared by

CH2M HILL

3840 Rosin Court, Suite 110
Sacramento, California 95834

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INTRODUCTION

The purpose of the Storm Drain Master Plan is to identify drainage system requirements and facilities necessary to accommodate planned growth within the community of Winters until the year 2010. This report addresses only portions of the area within the Urban Limit Line draining to Dry Creek and Putah Creek. Portions of the area draining to Moody Slough have been set aside for future studies due to the identified 100-year flood plain in that area and the need for any drainage plan to be part of a comprehensive flood control solution.

This study is based on the Winters General Plan, adopted in May 1992, which provides for a population of 12,500 by the year 2010.

This master plan can be used to evaluate system requirements for development proposals and to assist in determining an equitable basis for collecting impact fees to fund improvements that have regional versus development-specific benefits. The improvements identified herein have been laid out and sized based on existing topographic data and projections of future development. System piping for the storm drainage master plan will be altered slightly with changes in road layout, actual development, and any significant land use alterations. Therefore, pipe sizing and costs as presented in the master plan are subject to further change during final design.

STUDY AREA AND LOCAL HYDROLOGY

The City of Winters is located in Yolo County approximately 30 miles west of Sacramento, California, and 7 miles east (downstream) of Monticello Dam and Lake Berryessa. Winters is on the western edge of the Sacramento River Valley against the eastern edge of the Coast Range Mountains.

Portions of the Dry Creek, Putah Creek, Chickahominy Slough, and Moody Slough drainages affect drainage in the City of Winters (see Figure 1).

Most flooding problems in the vicinity of the City have been caused in part by impeded flow in Moody and Chickahominy Sloughs. Limited channel capacity and culvert capacity at County Road 89 and I-505 are the main contributors to flooding in Moody Slough. Several reaches of Chickahominy Slough are also undersized. The channel has been straightened to a west-east path, which is not directly downslope. As a result, when the channel overtops, the flows move southeasterly away from the channel until they hit the elevated I-505, which sends the flows south toward Winters.

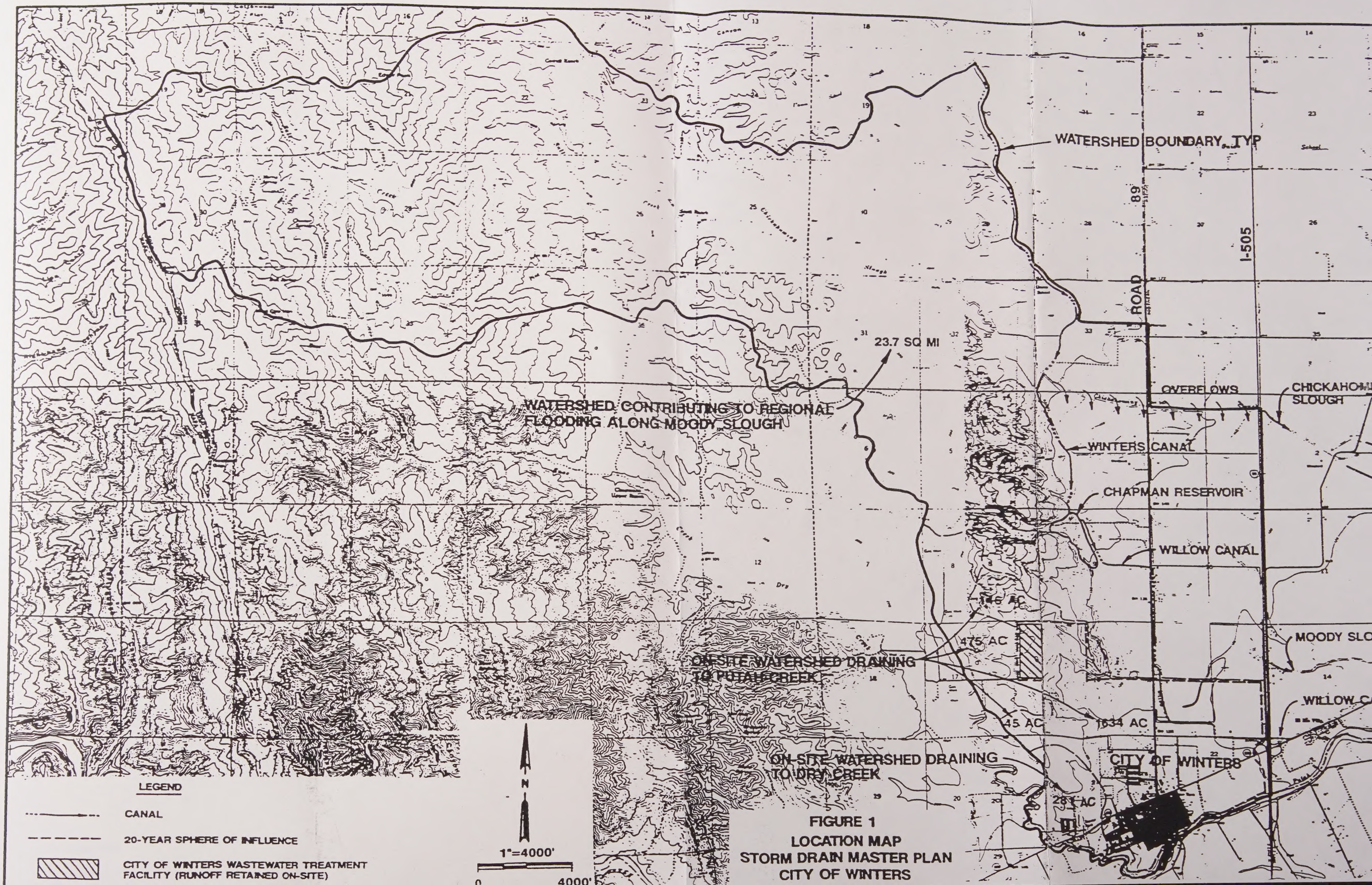

FIGURE 1
LOCATION MAP
STORM DRAIN MASTER PLAN
CITY OF WINTERS

The Winters Canal is another source of flood water to the study area. The canal, which is owned and operated by the Yolo County Flood Control and Water Conservation District, transports water from Cache Creek along the base of the Coast Range foothills for irrigation. The canal terminates at Chapman Reservoir, just north of the City of Winters. Outflows from Chapman Reservoir enter Willow Canal, flow south toward Winters, then east along Putah Creek to the City of Davis.

The canals cross a number of natural drainages. Following the irrigation season, wasteways are opened at the major drainages, and gates in the canals are closed to force winter flood waters out the wasteways into the natural drainages. One such wasteway exists about 3 miles north of Chickahominy Slough at Union School Slough. Over the next 3 miles, the canal picks up flood waters from minor drainages to the west and discharges to Chickahominy Slough. The gate at the canal siphon under Chickahominy Slough is closed in the winter so the canal is dry immediately south. It then intercepts minor drainages over the next mile until it flows into Chapman Reservoir. The Willow Canal is similarly wasted to Moody Slough in the winter.

Since the completion of Monticello Dam in 1957, flooding on Putah Creek has been virtually eliminated. The lowered water surface elevations in Putah Creek have also resulted in a lowering of flood water elevations in Dry Creek near the City of Winters. Both of these creeks have the capacity to contain the 500-year flood within their banks (SCS, 1976).

Winters is about 130 feet above mean sea level, with a general climate characterized by hot, dry summers and wet, cool winters typical of the California Central Valley. The average annual temperature is about 60°F. Temperatures in July, the warmest month, range from an average minimum of 56°F to an average maximum of 97°F. In January, the coolest month, the average minimum temperature is 36°F, and the average maximum is 55°F.

The average annual precipitation for Winters is about 20 inches (Table 1). Sixty percent of this falls during the winter flood season of December, January, and February. Only 0.2 percent of the precipitation occurs in the summer months.

Winters' population in 1990 was 4,693.

Table 1 City of Winters Mean Annual Rainfall			
Year	Total Rainfall (inches)	Year	Total Rainfall (inches)
1943	19.9	1967	35.5
1944	16.2	1968	15.1
1945	16.8	1969	29.4
1946	14.6	1970	25.8
1947	11.5	1971	18.8
1948	13.5	1972	10.9
1949	14.0	1973	33.5
1950	13.4	1974	21.4
1951	20.5	1975	22.4
1952	22.9	1976	6.2
1953	19.6	1977	9.4
1954	16.4	1978	34.4
1955	13.6	1979	19.5
1956	29.4	1980	32.8
1957	11.4	1981	15.3
1958	34.7	1982	37.0
1959	15.9	1983	43.8
1960	17.0	1984	20.3
1961	14.3	1985	17.8
1962	19.3	1986	32.8
1963	28.7	1987	12.3
1964	13.7	1988	18.4
1965	23.3	1989	15.1
1966	14.6	1990	14.4
Number of years			48
Average			20.4
Maximum			43.8
Minimum			6.2

Note: Records for Winters gage taken from National Weather Service, Department of Water Resources, and Winters Express data for water years beginning October 1 and ending September 30.

DRAINAGE FACILITIES

This portion of the master plan evaluates the adequacy of the existing storm drain system and provides a basis for sizing pipes within the City's Urban Limit Line. Storm drainage pipes will discharge to either Dry Creek or Putah Creek. Facilities have not been planned to provide storm drainage in the Moody Slough drainage basin. This area has been set aside for future study due to the identified 100-year flood plain and the need for any drainage plan in that area to be part of a comprehensive flood control solution.

SIZING CRITERIA

Sizing criteria most applicable to the City of Winters were developed from two sources: the Yolo County Basic Hydrology and Drainage Design Procedure (1965) and the City of Davis Engineering Design Standards (1990).

Land Use

For purposes of estimating runoff and determining drainage improvements, all land use was assumed to be at the ultimate level of development within the Urban Limit Line, based on the City of Winters General Plan, adopted early in May 1992.

Hydrology

A 10-year recurrence interval storm was used for analyzing the existing storm drain system and for sizing storm drains that will be needed in the future. Flows exceeding the capacity of storm drains were assumed to be carried by streets or flood easements. Finished floor elevations in new buildings must be constructed at least 1 foot above the level of the 100-year flood.

Long-term short-duration precipitation depth-duration-frequency data are unavailable for Winters. Nearby weather stations were evaluated based on years of record, annual precipitation, and topographic similarities. For this study, the rainfall data from Davis Station 2WSW were used. This station has 30 years of data for the 15-minute duration and 45 years of data for storm durations exceeding 1 hour. Table 2 presents the short-duration precipitation data, and Figure 2 presents the 10- and 100-year rainfall intensity curves.

Table 2
Short Duration Precipitation Depth-Duration-Frequency Table

Return Period In Years	Precipitation Depth (inches) for Indicated Duration (M = Minutes, H = Hours)									
	5M	10M	15M	30M	1H	2H	3H	6H	12H	24H
2	.12	.17	.23	.31	.41	.64	.77	1.12	1.49	1.93
5	.16	.23	.31	.41	.55	.85	1.04	1.51	2.00	2.59
10	.19	.27	.36	.48	.64	.99	1.21	1.75	2.33	3.01
20	.22	.31	.41	.54	.73	1.12	1.37	1.98	2.64	3.41
25	.22	.32	.42	.56	.76	1.17	1.42	2.05	2.73	3.53
40	.23	.33	.43	.57	.77	1.18	1.44	2.09	2.78	3.59
50	.25	.35	.47	.62	.83	1.29	1.57	2.27	3.02	3.90
100	.27	.39	.51	.68	.91	1.41	1.71	2.48	3.29	4.26
200	.29	.42	.55	.73	.99	1.52	1.85	2.68	3.56	4.61
1,000	.34	.49	.64	.86	1.15	1.78	2.17	3.14	4.17	5.39
10,000	.41	.59	.77	1.03	1.39	2.14	2.60	3.77	5.01	6.47
PMP[a]	.81	1.16	1.52	2.04	2.73	4.22	5.13	7.43	9.88	12.78
No. of Years Record	5	5	30	32	45	45	45	45	45	45
Record Year	1967	1967	1958	1947	1982	1982	1982	1962	1962	1962
Record Maximum	.220	.250	.460	.580	.900	2.200	2.200	2.430	3.540	5.190

[a]PMP = Probable Maximum Precipitation. Source: Davis 2WSW Station.

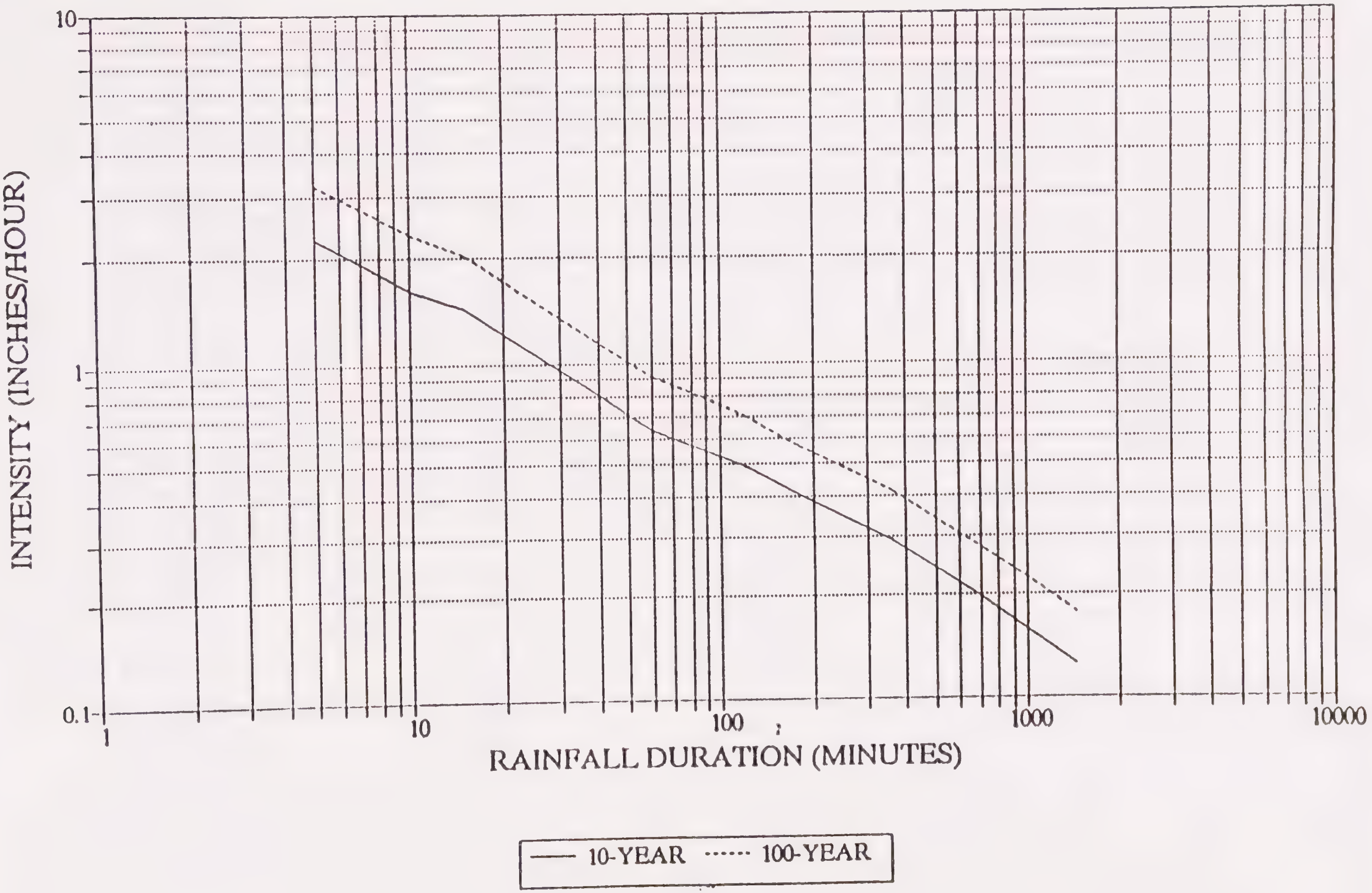

Figure 2
RAINFALL INTENSITY CURVES (DAVIS 2WSW)

The rational method was used to determine flow rates for the 10-year storm in basins of less than 640 acres (County of Yolo, 1965). The runoff flow rate was computed as:

$$Q = GCIA$$

where	Q	=	Design storm runoff (cfs).
	G	=	Geographic factor of 1.20. Used to transfer rainfall intensity data from Davis to Winters.
	C	=	Composite runoff coefficient representing the portion of rainfall that becomes runoff.
	I	=	Design storm rainfall intensity from Figure 2 (inches/hour).
	A	=	Upstream tributary drainage area (acres).

The following runoff coefficients were used in this study based on land use (City of Davis, 1990 and County of Yolo, 1965):

Land Use	"C" for the 10-Year Storm
Impervious	0.95
Commercial	0.80
Single-Family	0.45
Undeveloped Land	0.46
School	0.35
Park	0.25

The time of concentration (Tc) required to determine rainfall intensity (I) is based on the amount of time it takes runoff to travel from the farthest portions of a drainage basin to the facility being sized. Tc is the sum of the time components of overland flow, channel or gutter flow, and pipe flow.

For the purposes of this evaluation, Tc was determined using the following assumptions:

- Minimum time of concentration was assumed to be 10 minutes for residential and commercial areas.

- Time of overland flow (To) in residential areas was estimated to be 10 minutes. This was based on an average lot size of 7,500 square feet (Martin-Carpenter Associates, 1988), with 40 percent of the lot in impervious areas and 60 percent in lawn/green areas.

- To for undeveloped areas was based on the Soil Conservation Service (SCS) Method:

$$To = \frac{L^{0.8}(S_t+1)^{0.7}}{190\,S^{0.5}}$$

where
To = Overland flow travel time in minutes
L = Length of overland flow path in feet
S = Slope of overland flow in feet per foot
S_t = SCS soil water storage in inches and computed by the equation S_t = (1,000/CN) - 10 in which CN is the SCS curve number

- Time of gutter flow (Tg) was based on assuming a 4-inch depth of water in the gutter and a slope of 0.003 foot per foot (Yolo County, 1965).

- Time of channel or pipe flow was based on the Manning formula.

Pipe Flow

Analyses of the existing and future storm drain system assumed that all pipes were flowing full but not under pressure. All new pipes are assumed to be reinforced concrete pipe (RCP).

Pipe flow was estimated using Manning's formula:

$$Q = A\frac{1.486}{n}R^{2/3}S^{1/2}$$

where
Q = Peak flow (cfs)
n = Manning's n for RCP of 0.012, CMP of 0.024, and PVC of 0.010
R = Hydraulic radius using full pipe flow is D/4 (feet)
D = Diameter of pipe (feet)
S = Slope (feet per foot)
A = Area of pipe (square feet)

EXISTING SYSTEM

Capacity of the existing storm drain system was evaluated using a 10-year frequency storm. The existing system consists of 17 main lines installed at various times over the past 100 years. The majority of the storm drains consist of RCP with several short stubs of PVC and CMP. Pipe sizes range from 6 to 60 inches. All of the lines drain into Dry Creek or Putah Creek. The layout of the existing system is shown in Appendix A with estimated drainage areas provided in Appendix C.

Base mapping information for the analysis was taken from the following sources:

- Topography at 1-foot intervals—*Flood Hazard Analysis Study Area, City of Winters*. Laugenour and Meikle Civil Engineers, December 22, 1974.

- Layout and pipe sizes—*City of Winters Storm Drain System* (no date). Reviewed with City staff to determine flooding areas and pipe materials.

- Storm drain system inverts and slopes—*City of Winters Storm Drain System*. 1977.

- Regional drainage basins—*Monticello Dam Quadrangle, Photoinspected 1978*, and *Winters Quadrangle, Photoinspected 1973*. USGS 7.5-minute series maps.

As-built information does not exist for all pipes. What does exist was not field checked during this study because of time and budget limitations. Therefore, these preliminary results are of a general nature. Using criteria mentioned previously, the system was analyzed using a computer spreadsheet program. Results for the existing storm drain system appear in Appendix A. Improvements are referenced to main line numbers 900 through 5500. Each main line (i.e., 1500) is distinguished in Appendix A by circled node numbers (i.e., 1510, 1520, 1530, etc.) which are points at which flows were computed.

The analysis indicates that of the 17 main storm drain lines, 9 are undersized. Improvements required to provide 10-year storm flow capacity within the existing system are summarized in Table 3. This improvement scenario is contingent on future storm drain lines being installed west of Village Circle Street and west of the cemetery as part of future development in those areas. The total length of replacement pipe is approximately 15,000 feet of 18- to 42-inch pipe. The replacement pipes are highlighted over existing system pipes in Appendix B.

FUTURE SYSTEM

Projected growth for the City of Winters is described in the Winters General Plan, adopted in May 1992. The area requiring storm drainage facilities includes all the area within the Urban Limit Line defined in that plan.

Table 3 Replacement of Existing Storm Drain Main Lines							
Storm Drain Main Line[a]	Length of Pipe Required (feet)						
	18-inch	21-inch	24-inch	30-inch	36-inch	42-inch	Total
1500		250[b]	0	1,700	650		2,600
1800			450[b]				450
1900	1,000[b]						1,000
2000	400		250	800	1,650	1.650	4,750
2100	650	350	700				1,700
2200		700[b]	200[b]	500[b]			1,400
2400				400	1,150		1,550
2500	300		350	450			1,100
2600	450						450
Total	**2,800**	**1,300**	**1,950**	**3,850**	**3,450**	**1,650**	**15,000**

[a]Main line numbers refer to those shown in Appendixes A and B.
[b]Low priority improvements due to near adequate existing capacity.

The final pipe layout is presented in Appendix B. Anticipated drainage basins are presented in Appendix C. Because of the relatively flat terrain, drainage areas may change based on final road alignments and housing development. There are three new major storm drain lines with drainage areas ranging from 16 to 132 acres.

In addition to the criteria presented in the Design Criteria section, the following assumptions were made:

- Storm drains consist of reinforced concrete pipe with a Manning's roughness value (n) of 0.012.
- Storm drains have a minimum cover of 3 feet and a maximum cover of 10 feet.
- Initial storm drain slope is set at 0.003 and adjusted to meet topography requirements.
- Pipe sizing is based on a 10-year frequency storm.
- Minimum velocity is 2.5 feet per second when flowing 50 percent full or greater (City of Davis, 1990).

- Minimum new pipe size is 18 inches.

- Manholes and catch basin spacing is 500 feet.

The analysis appearing in Appendix B indicates that new pipe sizes will vary from 18 to 54 inches. Table 4 presents a summary of the future storm drain mainlines, including the drainage areas and linear feet of pipe.

COST ESTIMATES

Basis of Cost Estimates

Costs have been estimated for the storm drain systems with order-of-magnitude accuracy. This type of estimate is expected to be accurate within +50 to -30 percent. Order-of-magnitude estimates are prepared without detailed engineering analysis of various system components or site data. The estimates are based on conceptual plans of the storm drain systems and general cost-curve information for the various components.

The cost estimates have been prepared for guidance in project evaluation and implementation from information available at the time the estimate was prepared. Final project costs and resulting feasibility will depend on a number of variable factors. As a result, final project costs will vary from the estimates presented in this section.

Future System Costs

Estimated capital costs for the future storm drain mainline system are summarized in Table 5. A description of the cost development for the various components follows. Pipeline costs were estimated using a cost estimating database prepared by CH2M HILL. Actual material costs were included for pipe and backfill materials expected to be used on the project. Standard crews and equipment were assumed based on information presented in cost estimating guides.

Sacramento area labor and equipment rates for March 1992 were used to develop crew costs for the estimate. Production rates for installing pipe and related components were determined from cost estimating guides and supplemented with field data collected for similar projects.

Also included in the pipeline costs are catch basins and manholes at 500-foot intervals and major structures at an interval of one per mile. The following items are not included as part of estimated costs: easements, clearing and grubbing, surface restoration, and disposal of excess soil. These costs are assumed to be accounted for in the overall development of the areas requiring drainage.

Table 4 Future Storm Drain Main Lines														
Storm Drain Main Line[a]	Tributary Area (acres)	Length of Pipe Required (feet)												
		18-inch	21-inch	24-inch	30-inch	36-inch	42-inch	48-inch	54-inch	60-inch	72-inch	78-inch	84-inch	Total
1500				600	800									1,400
4000	115	500		2,100	1,600	750			1,000					5,950
5400	132			1,500	1,000			2,100						4,600
5500	16	700		100										800
Total		1,200		4,300	3,400	750		2,100	1,000					12,750

[a]Main line numbers refer to those shown in Appendix B.

Note: Catch basins and manholes are required at 500-foot intervals along main lines.

Table 5 Estimated Construction Costs for Future Storm Drain Main Line System				
Pipe (inches)	Quantity	Unit	Unit Cost	Cost ($1,000)
18	1,200	linear ft	45	54
24	4,300	linear ft	57	245
30	3,400	linear ft	70	238
36	750	linear ft	88	66
48	2,100	linear ft	128	268
54	1,000	linear ft	146	146
Subtotal	**12,750**			**1,017**
Contingency (30%)				305
Subtotal				**1,322**
Engineering, legal, and administration (20%)				264
Total				**1,586**
Note: See Appendix B for location of improvements. Price levels are as of March 1992.				

An allowance of 5 percent of the subtotal of the initial construction costs of the project components is included to account for the contractor's operational costs. These costs include mobilization and cleanup, field office, insurance, permits, overheads, and administration.

A construction cost contingency allowance of 30 percent of the subtotal estimated construction cost (including contractor's operational costs) is included. The 30 percent factor is recommended until more detailed engineering data are known. The resulting cost after application of the contingency allowance is the estimated construction cost.

Costs associated with engineering and construction management are included using an allowance of 17.5 percent of the construction cost. Administrative and legal costs associated with the project are estimated using an additional nondirect cost allowance of 2.5 percent of construction costs.

The estimated total project costs in Table 5 are the result of applying the nondirect costs to the estimated construction cost.

EXISTING SYSTEM COSTS

Estimated costs associated with replacement of 12,950 linear feet of existing storm drains on nine mains are presented in Table 6. These estimates were developed in the same manner as the future storm drain estimates, except a cost for surface restoration is included. Costs are based on the existing storm drains being removed and using the same alignment and grade for the new storm drains.

Table 6
Estimated Construction Costs for Replacement of
Existing Storm Drain Main Lines

Pipe (inches)	Quantity	Unit	Unit Cost	Cost ($1,000)
18	2,800	linear ft	67	188
21	1,300	linear ft	70	91
24	1,950	linear ft	77	150
30	3,850	linear ft	92	354
36	3,450	linear ft	109	376
42	1,650	linear ft	128	211
Subtotal	**15,000**			**1,370**
Contingency (30%)				411
Subtotal				1,781
Engineering, legal, and administration (20%)				357
Total				2,138

Note: See Appendix B for location of improvements. Price levels are for March 1992.

REGIONAL FLOOD CONTROL

Much of the area within Winters' Urban Limit Line lies in a designated 100-year flood plain (Figure 3). This flood plain is included in the Federal Emergency Management Agency (FEMA) Flood Insurance Study (1980). Construction of structures within these areas can only be permitted if first floor elevations are at least 1 foot higher than the 100-year flood elevations, or the area must be removed from the 100-year flood plain by constructing some form of flood control project. For either scenario, construction must not raise flood elevations upstream by more than 1 foot, according to FEMA criteria. Many local agencies are requiring criteria more strict than the FEMA criteria. A more conservative criterion is avoidance of negative impacts to property owners both upstream and downstream of the project. Negative impacts could include increased ponding upstream or increased flows downstream due to elimination of flood storage. If the area is to be removed from the regulatory flood plain, a letter of map revision (LOMR) is required from FEMA.

A small area of designated flood plain occurs in a low area in and adjacent to the Winters cemetery. This area would be removed from the flood plain by grading the area to drain to the proposed storm drain system (Mainline 5400 in Appendix B).

The larger designated flood plain lies along Moody Slough and its surrounding areas. Measures required to remove this area from the flood plain will be identified in future studies.

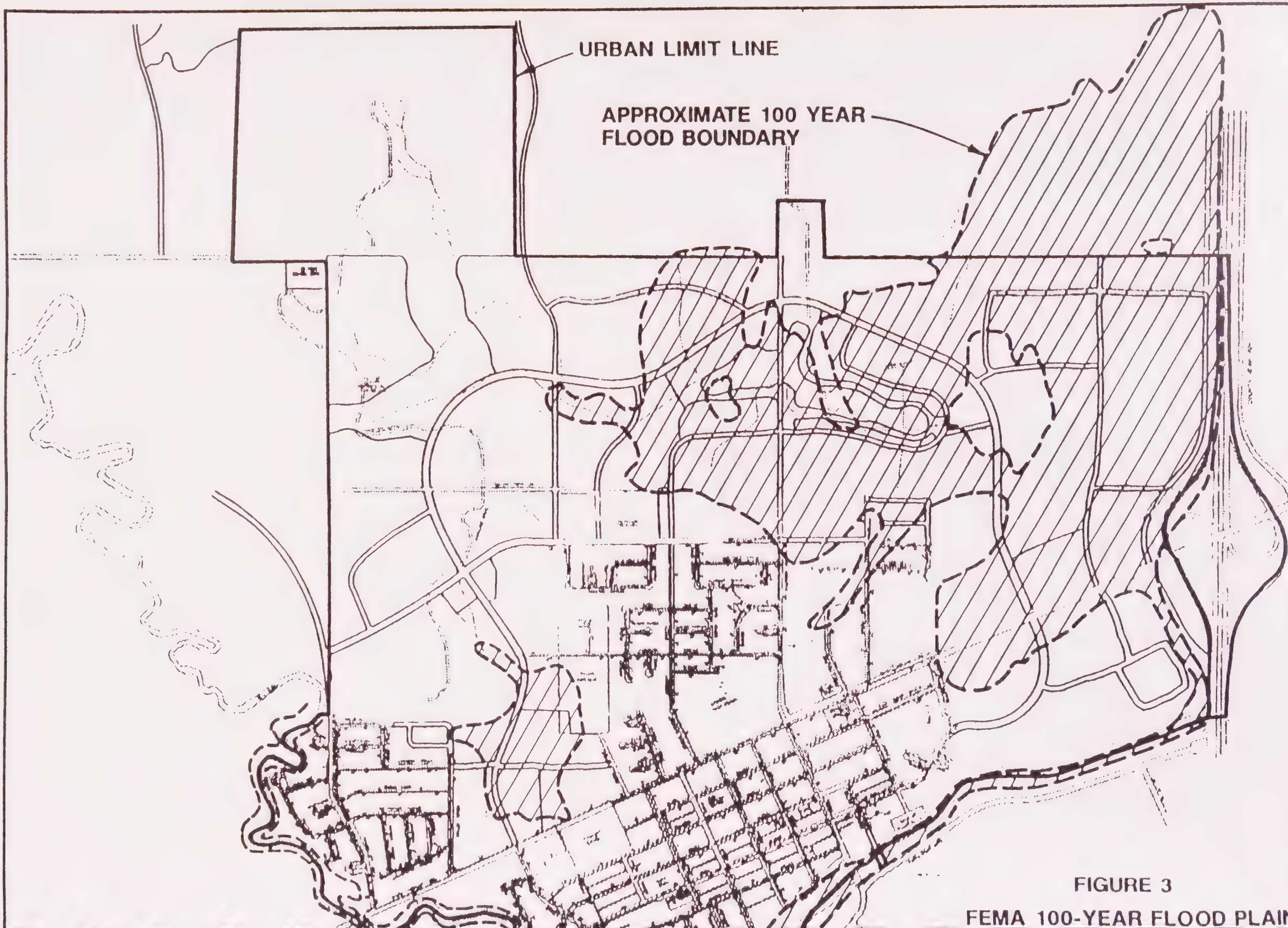

FIGURE 3
FEMA 100-YEAR FLOOD PLAIN

REFERENCES

City of Davis. *Engineering Design Standards (Preliminary).* March 22, 1990.

Federal Emergency Management Agency. *Flood Insurance Study, Yolo County, California, Unincorporated Areas.* June 1980.

United States Department of Agriculture, Soil Conservation Service. *Flood Hazard Analysis: City of Winters.* July 1976.

United States Department of Agriculture, Soil Conservation Service. *Investigation of Flood Problems: Chickahominy-Moody Slough Watershed, Yolo County, California.* January 1982.

United States Department of Agriculture, Soil Conservation Service. *Drainage Report, Chickahominy-Dry Slough Drainage Complex, Winters Davids Project.*

City of Winters. *General Plan.* Adopted May 1992.

County of Yolo. *Basic Hydrology and Drainage Design Procedure.* 1965.

Appendix A

EXISTING STORM DRAINS

APPENDIX A

STORM DRAIN CALCULATIONS - EXISTING SYSTEM

		Rational Equation Calculations 1/												Manning Equation Calculations For Pipe 2/						
Storm Drain Line	Upstream Node	Tributary Area (acres)	C	C*A	Summation of CA	Outter Length (ft)	Pipe Length (ft)	To (min)	Tg (min)	Tp (min)	Tc (min)	I (in/hr)	Q (cfs)	D (in)	Slope (ft/ft)	V (ft/s)	Capacity Q (cfs)	Additional Q Req'd (cfs)	Replacement Pipe Dia. (in) 3/	Comments
						1000														Upstream Conditions
900	910	7.0	0.45	3.15	3.15	0	500	10	17	0.0	27	1.03	3.89	15	0.0033	3.3	4.03	0.00		
	920	0.0	0.00	0.00	3.15	0	0	0	0	2.5	29	0.98	3.70							@ Dry Creek
Total Acreage =		7.0																		
						800														Upstream Conditions
1000	1010	4.0	0.45	1.80	1.80	0	150	10	13	0.0	23	1.11	2.40	12	0.004	3.1	2.45	0.00		Assumed Slope
	1020	0.0	0.00	0.00	1.80	0	0	0	0	0.8	24	1.09	2.35							@ Dry Creek
Total Acreage =		4.0																		
						250														Upstream Conditions
1100	1110	1.6	0.45	0.72	0.72	0	150	10	4	0.0	15	1.44	1.24	12	0.004	3.1	2.45	0.00		Assumed Slope
	1120	0.0	0.00	0.00	0.72	0	0	0	0	0.8	15	1.44	1.24							@ Dry Creek
Total Acreage =		1.6																		
						300														Upstream Conditions
1200	1210	1.9	0.45	0.86	0.86	0	250	10	5	0.0	15	1.44	1.48	12	0.004	3.1	2.45	0.00		Assumed Slope
	1220	0.0	0.00	0.00	0.86	0	0	0	0	1.3	16	1.37	1.41							@ Dry Creek
Total Acreage =		1.9																		Upstream Conditions
						250														
1300	1310	2.8	0.45	1.26	1.26	0	200	10	4	0.0	15	1.44	2.18	12	0.004	3.1	2.45	0.00		Assumed Slope
	1320	1.4	0.45	0.63	1.89	0	250	0	0	1.1	16	1.38	3.13	12	0.004	3.1	2.45	0.68		Assumed Slope
	1330	0.0	0.00	0.00	1.89	0	0	0	0	1.3	17	1.32	2.99							@ Dry Creek
Total Acreage =		4.2																		
						500														Upstream Conditions
1400	1410	5.2	0.45	2.34	2.34	0	300	10	8	0.0	18	1.28	3.59	18	0.003	3.5	6.25	0.00		
	1420	4.1	0.45	1.85	4.19	0	250	0	0	1.4	20	1.23	6.18	24	0.001	2.5	7.77	0.00		
	1430	4.9	0.45	2.21	6.39	0	250	0	0	1.7	21	1.17	8.97	24	0.004	4.9	15.54	0.00		
	1440	7.4	0.45	3.33	9.72	0	1100	0	0	0.8	22	1.14	13.30	24	0.004	4.9	15.54	0.00		
	1450	5.5	0.45	2.48	12.20	0	350	0	0	1.7	26	1.04	15.22	30	0.004	5.7	28.17	0.00		Assumed Slope
	1460	0.0	0.00	0.00	12.20	0	0	0	0	1.0	27	1.02	14.93							@ Dry Creek
Total Acreage =		27.1																		
						550														Upstream Conditions
1500	1502	20.0	0.42	8.33	8.33	0	600	10	9	0.0	19	1.25	12.50	24	0.0027	4.1	12.77	0.00	24	New pipe
	1505	4.0	0.45	1.80	10.13	0	800	0	0	2.5	22	1.16	14.10	30	0.0027	4.7	23.15	0.00	30	New pipe
	1510	4.1	0.45	1.85	11.98	0	350	0	0	2.8	24	1.08	15.52	18	0.0027	3.4	5.93	9.59	30	
	1520	5.3	0.45	2.39	14.36	0	250	0	0	1.7	26	1.04	17.92	18	0.0025	3.2	5.70	12.22	30	
	1530	2.9	0.45	1.31	15.67	0	750	0	0	1.3	27	1.01	18.99	18	0.0024	3.2	5.59	13.40	30	
						1350														Upstream Conditions
	1542	13.0	0.45	5.85	5.85	0	250	10	23	0.0	33	0.92	6.46	15	0.002	2.6	3.14	3.32	21	
	1545	3.9	0.45	1.76	23.27	0	350	0	0	1.6	34	0.89	24.85	23	0.0044	5.0	14.55	10.30	30	Duel pipes, replace both
	1550	3.5	0.45	1.58	24.85	0	650	0	0	1.2	35	0.87	25.94	30	0.0018	3.9	18.90	7.04	36	
	1560	2.1	0.45	0.95	25.79	0	300	0	0	2.8	38	0.83	25.69	30	0.004	5.7	28.17	0.00		Assumed Slope
	1570	0.0	0.00	0.00	25.79	0	0	0	0	0.9	39	0.82	25.38							@ Dry Creek
Total Acreage =		58.8																		

APPENDIX A

STORM DRAIN CALCULATIONS - EXISTING SYSTEM

Storm Drain Line	Upstream Node	Rational Equation Calculations 1/ Tributary Area (acres)	C	C*A	Summation of CA	Gutter Length (ft)	Pipe Length (ft)	To (min)	Tg (min)	Tp (min)	Tc (min)	I (in/hr)	Q (cfs)	Manning Equation Calculations For Pipe 2/ D (in)	Slope (ft/ft)	V (ft/s)	Capacity Q (cfs)	Additional Q Req'd (cfs)	Replacement Pipe Dia. (in) 3/	Comments
						750														
1600	1610	1.0	0.45	0.45	0.45	0	150	10	13	0.0	23	1.14	0.62	12	0.004	3.1	2.45	0.00		Upstream Conditions Assumed Slope, will be handled by future system
	1620	1.5	0.45	0.68	1.13	0	400	0	0	0.8	23	1.11	1.50	48	0.004	7.9	98.68	0.00		Assumed Slope
	1630	0.0	0.45	0.00	1.13	0	0	0	0	0.8	24	1.09	1.47							Jct. with 1640
						100														
	1635	4.8	0.80	3.84	3.84	0	400	10	2	0.0	15	1.44	6.64	24	0.004	4.9	15.54	0.00		Upstream Conditions Assumed Slope
	1640	3.8	0.45	1.71	6.68	0	400	0	0	1.3	25	1.06	8.49	48	0.004	7.9	98.68	0.00		Assumed Slope
	1650	3.7	0.45	1.67	8.34	0	0	0	0	0.8	26	1.04	10.41							@ Dry Creek
Total Acreage =		14.8																		
						300														
1700	1710	1.5	0.45	0.68	0.68	0	150	10	5	0.0	15	1.44	1.17	12	0.004	3.1	2.45	0.00		Upstream Conditions Assumed Slope
	1720	0,0	0,00	0,00	0,68	0	0	0	0	0.8	16	1,40	1,13							@ Dry Creek
Total Acreage =		1.5																		
						450														
1800	1810	4.6	0.53	2.46	2.46	0	300	10	8	0.0	18	1.32	3.89	21	0.0029	3.9	9.27	0.00		Upstream Conditions Jct. with 1830
						150														
	1820	4.3	0.45	1.94	1.94	0	250	10	3	0.0	18	1.32	3.07	15	0.002	2.6	3.14	0.00		Upstream Conditions
	1830	3.5	0.45	1.58	5.97	0	300	0	0	1.6	19	1.25	8.95	21	0.0015	2.8	6.66	2.28	24	
	1840	2.9	0.45	1.31	7.27	0	150	0	0	1.8	21	1.18	10.29	21	0.002	3.2	7.69	2.60	24	
	1850	0.0	0.00	0.00	7.27	0	0	0	0	0.8	22	1.16	10.12							@ Dry Creek
Total Acreage =		15.3																		
						250														
1900	1910	4.2	0.45	1.89	1.89	0	350	10	4	0.0	15	1.44	3.27	12	0.0028	2.6	2.05	1.22	18	Upstream Conditions
	1920	3.6	0.45	1.62	3.51	0	150	0	0	2.2	17	1.33	5.60	12	0.0044	3.3	2.57	3.04	18	
	1930	0.0	0.45	0.00	3.51	0	500	0	0	0.8	18	1.29	5.43	12	0.003	2.7	2.12	3.31	18	Assumed Slope
	1940	0.0	0.00	0.00	3.51	0	0	0	0	3.1	21	1.18	4.97							@ Putah Creek
Total Acreage =		7.8																		
						400														
2000	2004	5.4	0.45	2.43	2.43	0	100	10	7	0.0	17	1.35	3.94	6	0.002	1.4	0.27	3.66	18	Upstream Conditions Replace sump w/gravity
	2005	0.0	0.45	0.00	2.43	0	0	0	0	1.2	18	1.30	3.79							
						450														
	2010	5.7	0.37	2.13	2.13	0	350	10	8	0.0	18	1.32	3.37	15	0.002	2.6	3.14	0.23		Upstream Conditions No Area West
	2015	2.6	0.45	1.17	5.73	0	250	0	0	2.3	20	1.22	8.38	15	0.002	2.6	3.14	5.24	24	
	2020	6.9	0.45	3.11	8.83	0	500	0	0	1.6	21	1.17	12.40	15	0.002	2.6	3.14	9.26	30	
	2030	7.6	0.25	1.90	10.73	0	300	0	0	3.3	25	1.08	13.91	15	0.002	2.6	3.14	10.77	30	
	2035	5.0	0.45	2.25	12.98	0	250	0	0	2.0	27	1.03	16.04	15	0.002	2.6	3.14	12.91	36	
	2040	4.7	0.45	2.12	15.10	0	300	0	0	1.6	28	0.99	17.93	15	0.003	3.1	3.84	14.09	36	
	2045	3.2	0.45	1.44	16.54	0	250	0	0	1.6	30	0.96	19.05	28.3	0.0017	3.6	15.72	3.33	36	Duel Pipes, replace 15"
						900														
	2047	8.3	0.41	3.37	3.37	0	300	10	15	0.0	30	0.96	3.88	15	0.002	2.6	3.14	0.74	18	
	2050	14.0	0.48	6.69	26.59	0	250	0	0	2.0	32	0.93	29.67	28.3	0.002	3.9	17.05	12.62	36	Duel Pipes, replace 15"
	2060	11.2	0.45	5.04	31.63	0	300	0	0	1.1	33	0.91	34.53	28.3	0.0008	2.5	10.78	23.75	36	Duel Pipes, replace 15"

APPENDIX A

STORM DRAIN CALCULATIONS - EXISTING SYSTEM

Storm Drain Line	Upstream Node	Rational Equation Calculations 1/												Manning Equation Calculations For Pipe 2/						
		Tributary Area (acres)	C	C*A	Summation of CA	Gutter Length (ft)	Pipe Length (ft)	To (min)	Tg (min)	Tp (min)	Tc (min)	I (in/hr)	Q (cfs)	D (in)	Slope (ft/ft)	V (ft/s)	Capacity Q (cfs)	Additional Q Req'd (cfs)	Replacement Pipe Dia. (in) 3/	Comments
	2065	14.8	0.39	5.71	37.34	0	300	0	0	2.0	35	0.88	39.43	28.3	0.002	3.9	17.05	22.37	36	Duel Pipes, replace 15"
	2070	11.4	0.45	5.13	42.47	0	300	0	0	1.3	36	0.86	43.82	28.3	0.009	8.3	36.17	7.65	42	Duel Pipes, replace 15"
	2075	12.0	0.45	5.41	47.88	0	350	0	0	0.6	37	0.85	48.83	28.3	0.003	4.8	20.88	27.95	42	Duel Pipes, replace 15"
	2080	13.2	0.45	5.94	53.82	0	600	0	0	1.2	38	0.84	54.25	36.1	0.003	5.6	39.97	14.27	42	Duel Pipes, replace 24"
	2090	0.0	0.45	0.00	53.82	0	400	0	0	1.8	40	0.81	52.31	24	0.003	4.3	13.46	38.85	42	Assumed slope @ Putah Cr
	2095	0.0	0.00	0.00	53.82	0	0	0	0	1.6	41	0.80	51.66							
Total Acreage =		126.0																		
						450														Upstream Conditions
2100	2110	1.8	0.35	0.63	0.63	0	350	10	8	0.0	18	1.32	1.00	6	0.0022	1.5	0.29	0.71	18	
	2120	6.7	0.45	3.02	3.65	0	300	0	0	4.0	22	1.17	5.12	8	0.0048	2.6	0.91	4.21	18	
	2130	6.3	0.57	3.57	7.22	0	350	0	0	1.9	23	1.11	9.61	10	0.004	2.8	1.50	8.11	21	
	2140	8.7	0.53	4.65	11.87	0	700	0	0	2.1	26	1.05	14.95	12	0.004	3.1	2.45	12.50	24	Assumed Slope
	2150	0.0	0.00	0.00	11.87	0	0	0	0	3.7	29	0.97	13.81							@ Putah Creek
Total Acreage =		23.5																		
																				Upstream Conditions
						300														No Area West
2200	2205	3.1	0.42	1.30	1.30	0	300	10	5	0.0	15	1.44	2.24	12	0.002	2.2	1.73	0.51		Assumed Slope
	2215	5.2	0.38	1.97	3.27	0	700	0	0	2.3	17	1.33	5.21	15	0.002	2.6	3.14	2.07	21	Assumed Slope
	2225	6.9	0.45	3.11	6.37	0	200	0	0	4.6	22	1.16	8.07	18	0.002	2.9	5.10	3.77	24	Assumed Slope
						250														No Area West
	2231	2.5	0.45	1.13	1.13	0	400	10	4	0.0	15	1.44	1.94	15	0.002	2.6	3.14	0.00		Assumed Slope
	2232	3.3	0.45	1.48	2.61	0	550	0	0	2.6	18	1.31	4.10	18	0.002	2.9	5.10	0.00		Assumed Slope
	2230	5.2	0.40	2.06	11.04	0	500	0	0	1.2	23	1.12	14.84	24	0.002	3.5	10.99	3.85	30	Assumed Slope
	2235	6.9	0.45	3.11	14.15	0	300	0	0	2.4	25	1.08	17.99	30	0.002	4.1	19.92	0.00		Assumed Slope
	2240	4.5	0.45	2.03	16.17	0	400	0	0	1.2	27	1.03	19.99	36	0.002	4.6	32.40	0.00		Assumed Slope
	2245	7.0	0.45	3.15	19.32	0	550	0	0	1.5	28	1.00	23.18	36	0.002	4.6	32.40	0.00		Assumed Slope
	2250	7.6	0.45	3.42	22.74	0	500	0	0	2.0	30	0.96	26.20	42	0.002	5.1	48.87	0.00		Assumed Slope
	2260	6.2	0.53	3.32	26.06	0	300	0	0	1.6	32	0.93	29.08	42	0.002	5.1	48.87	0.00		
	2265	3.6	0.45	1.62	27.68	0	200	0	0	1.0	33	0.91	30.22	48	0.002	5.6	69.78	0.00		
	2270	10.7	0.49	5.27	40.91	0	550	0	0	0.6	33	0.90	44.18	48	0.0008	3.6	44.68	0.00		Added flow from 2430
	2285	19.8	0.68	13.43	54.34	0	750	0	0	2.6	36	0.86	56.07	48	0.001	3.9	49.34	6.73		Level Pipe
	2290	34.2	0.58	19.84	74.17	0	350	0	0	3.2	39	0.82	72.90	60	0.008	13.9	253.05	0.00		
	2310	20.2	0.82	16.48	90.65	0	300	0	0	0.5	39	0.82	89.19	60	0.008	13.9	253.05	0.00		
	2320	2.8	0.80	2.24	118.12	0	400	0	0	0.4	40	0.81	114.81	60	0.0038	8.9	174.40	0.00		Added flow from 2460
	2330	5.8	0.80	4.64	122.76	0	250	0	0	0.8	41	0.80	117.84	60	0.0038	8.9	174.40	0.00		
	2340	8.9	0.45	4.01	131.09	0	600	0	0	0.5	41	0.80	125.84	60	0.004	9.1	178.93	0.00		Assumed Slope
	2350	0.0	0.00	0.00	131.09	0	0	0	0	1.1	42	0.79	124.27							@ Putah Creek
Total Acreage =		164.2																		
						1100														Upstream Conditions
2400	2410	11.8	0.45	5.31	5.31	0	200	10	18	0.0	28	0.99	6.31	18	0.0015	2.5	4.42	1.89		No improvements in back
	2420	1.8	0.45	0.81	6.12	0	1350	0	0	1.3	30	0.97	7.12	18	0.0015	2.5	4.42	2.71		yards
	2430	4.1	0.45	1.85	7.97	0	50	0	0	9.0	39	0.83	7.93	15	0.001	1.8	2.22	5.72		
	2431	0.0	0.00	0.00	7.97	0	0	0	0	0.5	39	0.82	7.84							Flow to 2270
						500								15	0.001	1.8				Pipe S. of 2430
	2440	[illegible]	0.36	7.77	7.77	0	400	10	8	0.0	18	1.28	11.93	15	0.001	1.8	2.22	9.71	30	3 new catch basins

APPENDIX A
STORM DRAIN CALCULATIONS - EXISTING SYSTEM

Storm Drain Line	Upstream Node	Rational Equation Calculations 1/ Tributary Area (acres)	C	C*A	Summation of CA	Gutter Length (ft)	Pipe Length (ft)	To (min)	Tg (min)	Tp (min)	Tc (min)	I (in/hr)	Q (cfs)	Manning Equation Calculations For Pipe 2/ D (in)	Slope (ft/ft)	V (ft/s)	Capacity Q (cfs)	Additional Q Req'd (cfs)	Replacement Pipe Dia. (in) 3/	Comments
	2450	15.5	0.68	10.61	18.37	0	300	0	0	3.7	22	1.15	25.35	18	0.001	2.0	3.61	21.74	36	
	2460	9.8	0.70	6.86	25.23	0	850	0	0	2.4	24	1.08	32.70	10	0.002	2.0	1.06	31.63	36	New pipe to 2320
	2461	0.0	0.00	0.00	25.23	0	0	0	0	7.3	32	0.93	28.16							Flow to 2320
						200								18	0.004	4.1				Pipe S. of 2460
	2470	3.0	0.80	2.40	2.40	0	400	10	3	0.0	15	1.44	4.15	24	0.0008	2.2	6.95	0.00		
	2480	3.0	0.80	2.40	4.80	0	250	0	0	3.0	18	1.29	7.43	24	0.0012	2.7	8.51	0.00		
	2490	1.0	0.80	0.80	5.60	0	400	0	0	1.5	20	1.23	8.27	24	0.004	4.9	15.54	0.00		Assumed Slope
	2495	0.0	0.00	0.00	5.60	0	0	0	0	1.3	21	1.19	8.00							@ Putah Creek
Total Acreage =		71.5																		
						300														Upstream Conditions
2500	2510	1.0	0.45	0.45	0.45	0	100	10	5	0	15	1.44	0.78	12	0.011	5.2	4.06	0.00		
	2520	3.3	0.80	2.64	3.09	0	300	0	0	0.3	15	1.42	5.27	15	0.002	2.6	3.14	2.13	18	
	2530	2.2	0.80	1.76	4.85	0	200	0	0	2.0	17	1.33	7.74	15	0.002	2.6	3.14	4.60	24	
	2540	3.0	0.80	2.40	7.25	0	150	0	0	1.3	19	1.27	11.05	15	0.002	2.6	3.14	7.91	24	Assumed Slope
	2550	5.0	0.80	4.00	11.25	0	450	0	0	1.0	20	1.23	16.61	15	0.002	2.6	3.14	13.47	30	Assumed Slope & Pipe
	2560	0.0	0.00	0.00	11.25	0	0	0	0	2.9	22	1.14	15.39							@ Putah Creek
Total Acreage =		14.5																		
						450														Upstream Conditions
2600	2610	4.5	0.68	3.08	3.08	0	100	10	8	0.0	18	1.32	4.87	8	0.002	1.7	0.59	4.28		
	2620	2.0	0.63	1.25	4.33	0	450	0	0	1.0	18	1.27	6.59	8	0.002	1.7	0.59	6.00	18	New pipe to 2340
	2630	0.0	0.00	0.00	4.33	0	0	0	0	4.5	23	1.12	5.81							Assumed Slope @ Putah Cr
Total Acreage =		6.5																		

Notes:

1. Q = GCIA, where

   G (Geogr. Factor) = 1.20
   C factors = 0.45 (Low, medium density residential)
   0.80 (Commercial, light industrial, high density residential)
   0.35 (Schools)
   0.25 (Parks)
   0.46 (Undeveloped land)
   0.95 (Impervious areas)
   I (intensity) = 10-yr intensity taken from Figure 2 for the computed Tc

   To = 10 minutes for residential areas.
   Tg = Time of gutter flow from Yolo County, 1965 Nomagraph
   where Vgutter = 1 ft/sec
   Tp = Estimated from pipe length and velocity
   Tc = 15 minutes minimum (City of Davis)

2. Q = 1.486AR^(2/3)S^(1/2)/n for pipe flowing full, where
   A = Cross sectional area of pipe (3.14159D^2/4)
   R = Hydraulic Radius (D/4)
   S = Invert slope of pipe
   n for RCP = 0.012

3. Required Replacement Pipe assumes same alignment, length and slope as existing pipe. See Appendix B for location of required improvements.

Appendix B

FUTURE STORM DRAINS

APPENDIX B

STORM DRAIN CALCULATIONS - FUTURE SYSTEM

Storm Drain Line	Upstream Node	Ground Elev. (ft)	Rational Equation Calculations 1/ Tributary Area (acres)	C	C*A	Summation of CA	Gutter Length (ft)	Pipe Length (ft)	To (min)	Tg (min)	Tp (min)	Tc (min)	I (in/hr)	Q (cfs)	Manning Equation Calculations For Pipe 2/ D (inch)	Invert Elev. (ft)	Slope (ft/ft)	V (ft/s)	Capacity Q (cfs)
							500												
4000	4010	126.6	5.0	0.80	4.00	4.00	0	500	10	8	0.0	18	1.28	6.15	18	121.6	0.003	3.5	6.25
											2.4								
							300												
	4020	123.2	7.0	0.80	5.60	5.60	0	1100	10	5	0.0	15	1.44	9.68	24	118.2	0.003	4.3	13.46
	4030	126.2	10.0	0.80	8.00	17.60	0	750	0	0	4.3	21	1.19	25.20	36	113.9	0.003	5.6	39.68
											2.2								
							500												
	4040	126.0	27.0	0.80	21.60	21.60	0	1000	10	8	0.0	18	1.28	33.19	30	120.5	0.008	8.1	39.84
											2.1								
							300												
	4050	130.0	20.0	0.45	9.00	9.00	0	1000	10	5	0.0	15	1.44	15.55	24	124.5	0.007	6.5	20.55
	4060	129.0	19.4	0.55	10.70	19.70	0	600	0	0	2.5	18	1.31	31.06	30	117.0	0.007	7.6	37.27
	4070	127.0	26.9	0.67	17.99	76.89	0	1000	0	0	1.3	23	1.12	103.68	54	110.2	0.003	7.4	117.00
											2.3								
Total Acreage =			115.3																
							500												
5400	5410	153.0	17.6	0.42	7.34	7.34	0	600	10	8	0.0	18	1.28	11.28	24	148.0	0.008	7.0	21.97
	5420	148.0	4.5	0.80	3.60	10.94	0	900	0	0	1.4	20	1.23	16.09	24	143.2	0.008	7.0	21.97
	5430	141.0	25.4	0.45	11.43	22.37	0	1000	0	0	2.1	22	1.15	30.97	30	135.5	0.006	7.0	34.51
	5440	135.0	30.9	0.43	13.24	35.61	0	1700	0	0	2.4	24	1.09	46.42	48	128.0	0.001	3.9	49.34
	5450	140.0	53.2	0.44	23.36	58.96	0	400	0	0	7.2	31	0.93	66.02	48	126.3	0.002	5.6	69.78
Total Acreage =			131.6																
							500												
5500	5510	165.0	8.0	0.45	3.60	3.60	0	700	10	8	0.0	18	1.28	5.53	18	160.0	0.007	5.4	9.54
	5520	160.0	8.3	0.45	3.74	7.34	0	100	0	0	2.2	20	1.20	10.56	24	154.6	0.006	6.1	19.03
Total Acreage =			16.3																

Notes:

1. Q = GCIA, where

G (Geogr. Factor) = 1.20

C factors = 0.45 (Low, medium density residential)
0.80 (Commercial, light industrial, high density residential)
0.35 (Schools)
0.25 (Parks)
0.46 (Undeveloped land)
0.95 (Impervious areas)

I (intensity) = 10-yr intensity taken from Figure 3 for the computed Tc

To = 10 minutes for residential and commercial areas.
Tg = Time of gutter flow from Yolo County, 1965 Nomagraph
where Vgutter = 1 ft/sec
Tp = Estimated from pipe length and velocity
Tc = 15 minutes minimum (City of Davis)

2. Q = 1.486AR^(2/3)S^(1/2)/n for pipe flowing full, where
A = Cross sectional area of pipe (3.14159D^2/4)
R = Hydraulic radius (D/4)
S = Invert slope of pipe, assumed > 0.003

Upstream-most node in each system invert assumed 5 ft below grade
Pipe cover assumed between 3 and 12 feet
n for RCP = 0.012

Appendix C

DRAINAGE BOUNDARIES

DRAINAGE
BOUNDARIES

FUTURE STORM
DRAIN SYSTEM

EXISTING STORM
DRAIN SYSTEM

Oversized Map or Foldout not scanned.

Item may be viewed at the
Institute of Governmental Studies Library, UC Berkeley.